Electric Charges and Field

Important Formulas

1. **Coulomb's Law** (Force between two point charges)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

   where $\varepsilon_0 = 8.854 \times 10^{-12}\, C^2 N^{-1} m^{-2}$ is the permittivity of free space.

2. **Electric Field (E) due to a Point Charge**

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

   - Direction: Radially outward for positive charge, inward for negative charge.

3. **Electric Dipole Moment (p)**

$$p = q \times 2a$$

   - Direction: From negative to positive charge.

4. **Electric Field due to a Dipole**
   - **On the axial line**:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

   - **On the equatorial line**:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

   - Direction: Opposite to dipole moment.

5. **Torque (τ) on an Electric Dipole in a Uniform Field**

$$\tau = pE\sin\theta$$

   - Maximum when $\theta = 90^\circ$.

6. **Electric Flux (ϕ)**

$$\phi = \oint \mathbf{E} \cdot d\mathbf{S}$$

   - Measured in Nm^2C^{-1}.

7. **Gauss's Law**

$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

   - Useful for symmetrical charge distributions.

8. **Electric Field due to a Uniformly Charged Infinite Plane Sheet**

$$E = \frac{\sigma}{2\varepsilon_0}$$

9. **Electric Field due to a Long Straight Charged Wire**

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

10. **Electric Field due to a Charged Sphere**
    - **Outside the sphere**:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

    - **Inside a conducting sphere**:

$$E = 0$$

Units and Constants

1. **Charge of an Electron**: $e = 1.6 \times 10^{-19} C$
2. **Permittivity of Free Space**: $\varepsilon_0 = 8.854 \times 10^{-12} C^2 N^{-1} m^{-2}$
3. **Coulomb's Constant**: $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 N m^2 C^{-2}$
4. **Electric Flux Unit**: $N m^2 C^{-1}$
5. **Electric Field Unit**: $N C^{-1}$ or $V m^{-1}$
6. **Electric Dipole Moment Unit**: $C m$
7. **Surface Charge Density (σ)**: $C m^{-2}$
8. **Linear Charge Density (λ)**: $C m^{-1}$
9. **Volume Charge Density (ρ)**: $C m^{-3}$